National Defence / Défense nationale

Canada

EFFECTS ON SCRUBBER ENDURANCE OF STORING SODA LIME IN CF REBREATHERS

DISTRIBUTION STATEMENT A

Approved for public release.
Distribution Unlimited

Defence and Civil
INSTITUTE OF ENVIRONMENTAL MEDICINE

INSTITUT DE MEDECINE ENVIRONNEMENTALE
pour la défense

1133 Sheppard Avenue West, PO Box 2000, North York, Ontario, Canada M3M 3B9
Tel. (416) 635-2000
Fax. (416) 635-2104

Nov 1995 DCIEM No. 95-47

EFFECTS ON SCRUBBER ENDURANCE OF STORING SODA LIME IN CF REBREATHERS

D.J. Eaton

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
North York, Ontario
Canada M3M 3B9

ABSTRACT

Canadian Forces divers using rebreather diving apparatus are currently restricted to pre-dive preparation times of only 6 hours. A proposal was made to increase this time to 7 days. Theoretically, this was possible; however, no empirical data were available to indicate that the chemical carbon dioxide absorbent could survive an extended storage period in Canadian Forces rebreathers. Consequently, the Experimental Diving Unit of the Defence and Civil Institute of Environmental Medicine conducted a study to determine if storage of soda lime would reduce the carbon dioxide scrubber endurance. The tests measured scrubber endurance using proposed NATO standard procedures under three conditions: (a) no storage; (b) seven days of storage; and (c) 1 hour under the endurance test conditions, followed by 7 days storage and then completion of the endurance test. The results indicated no difference between the three conditions; thereby, supporting the proposal for up to 7 days of storage. On the other hand, issues related to cold weather operations, biological hazards, heavy exertion and accelerated material wear imposed some restrictions on rebreather storage.

Executive Summary

The Canadian Forces (CF) uses three rebreathers: (a) the Canadian Clearance Diving Apparatus (CCDA), (b) the Canadian Underwater Mine Apparatus (CUMA) and (c) the S-10. In a rebreather, gas is recycled to conserve the on-board supply and to reduce acoustic signatures. Carbon dioxide in the gas must be removed before it can be rebreathed by the diver. The filtering is done by breathing the gas through a chemical filter called a scrubber. The scrubber contains granular soda lime which reacts with the carbon dioxide to absorb it. All three diving apparatus use an identical carbon dioxide scrubber. Before a dive, the diver charges the scrubber with soda lime and then seals it into its housing on the rebreather. Present regulations specify that the scrubber can be charged up to 6 hours before a dive. If a dive is not started within this period, the scrubber must be re-charged with fresh soda lime. The regulations do allow for multiple dives to be completed with the same charge of soda lime, but the scrubber must be charged 180 minutes after the start of the first dive. These regulations were considered too restrictive and wasteful for operating time and resources. A proposal was made to extend the preparation period to seven days. No empirical data were available to indicate that the soda lime's capacity to absorb carbon dioxide would be affected by storage in the rebreather. Consequently, an experiment was conducted to examine the effect of seven days of storage on the endurance of the carbon dioxide scrubber.

Three storage conditions were examined: (1) no storage, (2) storage for seven days and (3) use for 1 hour followed by seven days of storage and then use again. The conditions were compared using a proposed NATO standard method for measuring the endurance of the carbon dioxide scrubber (*i.e.*, the time required for scrubber outlet carbon dioxide concentration to reach 0.5% volume by volume).

The endurance tests were completed with 3 CCDA and 5 S-10 rebreathers. They were each in turn submerged in 0 to 3C water and subjected to breathing flows produced by a reciprocating pump. Gas in the exhale phase of the pump stroke was heated, humidified and injected with carbon dioxide (1.6 litres per minute) to reproduce gas exhaled by a diver working at a moderate rate. Gas leaving the scrubber was analysed for carbon dioxide content and the test was completed when the level reached 0.5% volume by volume. The total time completed in the test was the endurance. Each rebreather was subjected to each test condition once for a total of 15 endurance tests.

Results showed no difference between the endurance of the three conditions; however, other factors related to multiple dives with the rebreathers would restrict their operational use. These factors were associated with storage of wet equipment which would cause ice formation and possible equipment failure in sub-freezing temperatures, biological growth and subsequent toxicological hazards and pre-mature deterioration of rebreather components. Short duration, multiple dives were also revealed as a problem factor as higher carbon dioxide rates can be maintained for these shorter periods; thereby, reducing the endurance of the scrubber.

Recommendations made included the updating of diving regulations to permit the seven-day storage period with restrictions on multiple use which require cleaning and drying of the scrubber between dives. A recommendation was also made to develop a method for adjusting endurance for higher work rates during shorter dives.

Table of Contents

INTRODUCTION

The Canadian Forces (CF) uses three rebreathers: (a) the Canadian Clearance Diving Apparatus (CCDA, known commercially as Siva 55), (b) the Canadian Underwater Mine Apparatus (CUMA, known commercially as Siva+) and (c) the S-10. These rebreathers recycle gas to conserve the on-board gas supply and to reduce acoustic signatures. To rebreath the gas the rebreather must filter out the carbon dioxide (CO_2) produced by the diver before the gas can be inhaled again. The filtering is accomplished by breathing the gas through a granular bed of a chemical mixture called soda lime. This filter is known as a CO_2 scrubber. All three CF rebreathers are manufactured by Fullerton, Sherwood Engineering Limited (FSEL) with a common CO_2 scrubber design.

Contact with mine countermeasures diving groups in other navies (Netherlands, Belgium, France, South Africa) indicated that it was possible to precharge a rebreather scrubber with soda lime and then, with the scrubber sealed inside the rebreather, store the apparatus for future use. Claims of storage periods of 7 days have been made but there was no objective evidence that the operational endurance of CF rebreathers was unaffected.

CF regulations [1] regarding the charging of the CO_2 scrubber require that the CO_2 absorbent must be changed after 180 minutes of diving. If not used immediately, it can be stored in the rebreather for 6 hours or, if the 180 minute rated endurance is not reached in a single dive, multiple dives can be done until the scrubber needs recharging 180 minutes after the start of the first dive.

These limits were developed because of a lack of information regarding the effect of storing soda lime in a rebreather. A comparison of storing the soda lime in the original packaging to storing in a rebreather suggests that there should be little difference and that scrubber endurance should not be affected. However, in the absence of empirical data, a conservative estimate of a safe storage period of time was established. Discussions with operational personnel revealed that a working day was considered to be a reasonable period of time for re-charging

scrubbers. The scenario envisioned was the preparation of the apparatus at the beginning of the day followed by up to six hours of storage which would normally coincide with the last dive of the day. Consequently, the six hour storage period was established as a compromise based on the information available at the time. Greater knowledge of the effects of storing CO_2 absorbent in the CF rebreathers would possibly allow for longer storage periods.

Increasing the allowable storage period would significantly increase the flexibility of operations and improve efficiency. Rather than spend a valuable part of each day charging the rebreathers with soda lime, divers could use inactive periods to prepare the scrubbers well in advance of the expected dive. Also, soda lime would not be wasted if a planned dive was postponed beyond the six hour limit.

To predict the allowable period for storing soda lime in a CF rebreather, it could be assumed that the storage conditions in the rebreather are equivalent to that in the original soda lime containers. The sealing mechanisms, whether in CCDA, CUMA or S-10, are such that there would be minimal gas exchange between the rebreather and the ambient air. Soda lime stored inside the rebreather would not be exposed to free moving air or any other source of CO_2. For example, almost 400 litres (L) of air would have to pass through the scrubber to reduce the soda lime absorption capacity by 10%. This would never happen in a properly sealed rebreather. The water content of soda lime is also an important factor in its ability to absorb CO_2. The rebreather seal would prevent any net change in water content. Therefore, the total endurance of the scrubber should be the same whether the scrubber was charged and used immediately or if it was stored. If CO_2 exposure and moisture content were the only factors to consider, then there should be no effect on endurance.

However, there are other confounding variables. The most important factor is particle settling. When exposed to even small vibrations, CO_2 absorbents will settle with time [2]. This settling can cause channeling of the gas through the

scrubber. This bypasses the CO_2 absorbent which can lead to CO_2 poisoning. Therefore, a time period was desired that would increase the pre-dive preparation period but avoid the possible effects of long-term settling.

Discussions with users and examination of operational activities suggested that a seven day storage period would be suitable. Since many exercises occur on a weekly basis, it would be useful to prepare apparatus on the last day of a week and then be able to store the apparatus for use during the following week. Therefore, a seven day storage period was proposed.

Integral to the question of extended storage was the possibility for multiple dives during the seven day period. That is, could the scrubber be used for a period less than 180 minutes, then stored and used again until 180 minutes of use were achieved? If feasible, this possibility would also improve operational effectiveness.

Consequently, the Experimental Diving Unit (EDU) of the Defence and Civil Institute of Environmental Medicine (DCIEM) completed an experiment to examine two conditions of storage. The first was the case where an apparatus was pre-charged with soda lime and sealed for seven days before it was put into service. The second was where an apparatus was used for 1 hour and then was stored for use seven days in the future. The purpose of the tests was to establish whether scrubber endurance when the soda lime was stored in the rebreather for up to seven days was lower than the endurance of unstored soda lime.

METHODS

General. The unmanned scrubber endurance was determined for five identical carbon dioxide scrubbers (two S-10 and three CCDA rebreathers) under three separate conditions. The first condition (Control) established a baseline for comparison by determining the endurance with scrubber cartridges charged within one hour of starting the test. The second condition (Store/Test) determined the endurance with cartridges charged seven days prior to the test. The third con-

dition (Test/Store/Test) determined endurance with cartridges that were charged, tested for one hour, sealed for seven days and then tested until completion of the endurance determination. The activity of the soda lime [3] was measured to ensure that soda lime quality was not a confouning variable. The two experimental conditions were compared to the control condition to establish whether scrubber endurance decreased with storage in the rebreathers.

Location. The experiment was completed in EDU's Unmanned Test Facility (UTF). The facility was set-up for standard carbon dioxide scrubber endurance tests [3]. The rebreathers were submerged in water that was maintained at a temperature between 0°C and 3°C. The tests were completed using a breathing machine equipped with carbon dioxide injection, make-up air injection and exhale gas humidification systems. The hyperbaric chamber was not pressurized.

Soda Lime. Soda lime was taken from EDU supplies (Molecular Products Ltd., Sofnolime, 8-12 mesh British Standard). EDU determined the activity [3] of each charge of soda lime from a sample taken prior to filling the scrubber.

Breathing Apparatus. Storage of the charged scrubber cartridges was done using two S-10 and three CCDA. Because each apparatus uses identical carbon dioxide scrubbers and comparable breathing loops, inter-model variations were considered negligible.

Procedures. Soda lime samples for activity testing were taken by first mixing two bags of soda lime together. (Two 1.4 kilogram bags are required to fill the scrubber.) A 0.25 L sample was scooped from the mixed soda lime. The scrubber was filled and any remaining soda lime was added to the original 0.25 L sample. The activity samples were sealed in plastic (MacMillan-Bloedel, 4 mil polyethylene) until tested. Testing consisted of one test per sample.

Variation in packing density would have arose as a confounding variable if a number of divers were involved. To control this variability, the scrubber was

charged by the same Clearance Diver. Once charged, the scrubber was installed in the breathing apparatus and then, depending on the experimental condition, it was either stored for seven days or immediately installed in the UTF for the endurance determination test. Storage involved evacuating the breathing loop, rotating the mouthpiece barrel valve to seal the breathing loop and placing the apparatus in a room kept between 20°C and 22°C. When taking the apparatus out of storage the breathing loop was checked for leaks by observing whether the counterlung remained completely deflated and the breathing hoses were still longitudinally compressed.

Scrubber endurance was determined following draft NATO procedures [4] with constant carbon dioxide injection at 1.6 Litres per minute ($L{\cdot}min^{-1}$) (at 0°C, 1 atmosphere) and breathing machine settings of 2 L stroke volume and 20 strokes per minute. Counterlung volume was maintained by monitoring the pressure inside the breathing loop. Air was added as required to prevent collapse of the counterlung.

Endurance was defined as the time required for the CO_2 concentration of the gas leaving the scrubber to reach 0.5% volume by volume. The CO_2 concentration was measured by continuous infra-red analysis (Analytical Development Co. Ltd, Hoddesdon, England, Model PM 3A, 0 - 5%) of a 0.3 $L{\cdot}min^{-1}$ sample extracted downstream of the scrubber exit port.

For the Test/Store/Test condition the apparatus was removed from the UTF after the first hour of testing, the breathing loop was evacuated, the mouthpiece sealed and the apparatus stored for 7 days. The endurance test was completed after the 7 day storage. The endurance was determined as the sum of the 60 minutes before storage plus the endurance after storage.

Design. Data from all conditions consisted of endurance in minutes for each scrubber endurance test. A one-way analysis of variance, α=0.05, was used to test for differences between the three conditions.

RESULTS

In all 15 cases the stored breathing apparatus did not lose their seal. The counterlungs remained flat and a negative pressure remained in the breathing loop as indicated by the lengthwise compression of the breathing hoses.

Inspection of the scrubbers after the endurance tests were completed revealed premature deterioration of six of the 10 foam compression inserts used in the scrubber. Soda lime was deeply embedded into the foam and the weight of the inserts was reduced between 17% and 79%.

All soda lime activity samples passed the minimum requirement of 65 minutes [4]. The mean activity of the 15 samples was 81 minutes with a standard deviation of 3.6 minutes.

Figure 1. shows boxplots of the endurance data for the three conditions. Superimposed on the boxplots are the sample means. The boxplots for the Store/ Test and Test/Store/Test conditions reveal strong outliers, consequently, rather than use a classical F test which may be affected by outliers, the more robust Kruskal-Wallis one-way analysis of variance was employed. A comparison of the sample means via Kruskal-Wallis found $p = 0.43$ which was greater than the $\alpha = 0.05$ desired. Consequently, there was no evidence to support a difference between the three conditions.

DISCUSSION

The experiment compared the endurance of carbon dioxide scrubbers tested immediately after being charged with soda lime to that of scrubbers that had been charged and stored for seven days and to that of scrubbers charged, used for one hour, stored for seven days and then tested to endurance. The results of the comparison showed no evidence of a significant difference between the three conditions. This supported the proposal that up to seven-days of storage is

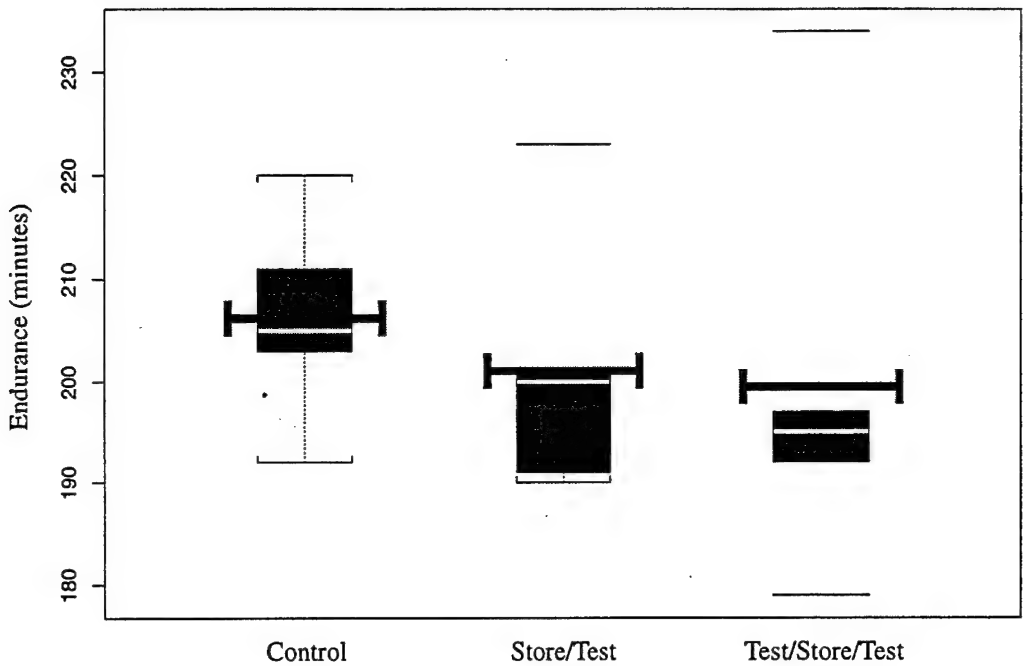

Figure 1. Scrubber endurance distributions for three storage conditions, n=5 in each condition. The horizontal white lines in the interior of the boxes identify the medians of the data. The lower limit of the boxes are the first quartile while the upper limit is the third quartile. (The difference between the third and first quartile is the interquartile distance, a measure of the spread of the data.) The whiskers (the dotted lines extending from the top and bottom of the Control and from the bottom of the Seven Day boxes) extend to the extreme values of the data. Outliers (those lying outside 1.5 times the interquartile distance from the median) are indicated by flat horizontal lines. The mean values of the data are indicated by thick horizontal lines terminated with the vertical bars.

acceptable for pre-charging CF rebreathers and for multiple use of rebreathers. However, there were other considerations. Vibration and storage temperature were factors considered for both the simple pre-charging (Store/Test) and the multiple use cases (Test/Store/Test).

These tests were done in the low vibration environment of a laboratory. Moving vehicles, whether on land, air or sea, will have levels of vibration which

could cause settling of the soda lime. Settling can cause the gas to be channeled past the soda lime and thereby lower the endurance. No specific data were available to identify what total vibration exposure would cause enough settling to produce significant channeling. On the other hand, with all three CF diving rebreathers there is a quick visual and aural test [5] of the scrubber cartridge that will determine if the scrubber is adequately packed. The scrubber endurance will not be compromised by doing this quick check. If necessary the scrubber can be topped up with soda lime to prevent channeling. Therefore, procedures are available to compensate for vibration related settling.

Pre-packing and storage in temperatures as low as -6.7°C will not pose a problem as shown by Presswood [6]. In an experiment where AGASORB (equivalent to Sofnolime) was stored at -6.7°C for 24 hours prior to use, the scrubber endurance of the Draeger Lar V was not significantly reduced compared to tests done with soda lime that had not been frozen.

However, using the rebreather and then storing it in freezing temperatures could seriously affect the apparatus performance. The CF has experienced these problems when trying to complete multiple dives during winter operations. Symptoms include ice formation in the mouthpiece and counterlung relief valves as well as the CUMA diluent regulators. Precautions to be used during cold weather operations are included in the CF rebreather manuals [7]. These precautions will minimize the problems. Nevertheless, prolonged storage below 0°C may not permit safe use of the apparatus without re-warming.

Use of a rebreather followed by storage could also create a toxic hazard from bacteria, fungi and moulds. The magnitude of the hazard is not known; however, the DCIEM Health Hazards Group recommended cleaning and drying of the breathing loop prior to storage. Since the scrubber cartridge is also exposed to the phlegm, expectorate, saliva and condensate, it would need to be cleaned to prevent "seed" material from re-entering the breathing loop. This would not be practical. Therefore, until the magnitude of the hazard is known, use followed by

extended storage is not recommended. If, however, operations necessitate multiple use and storage, the breathing loop (not including the scrubber cartridge) should be cleaned. The scrubber cartridge should at least be wiped down with the disinfectant used for breathing loop cleaning. An attempt will be made to quantify the biological hazard during future experiments involving CF rebreathers. Until then, users must recognize that there is some risk of biological hazard associated with using, storing and then re-using a rebreather.

The storage of the soda lime in the scrubber after it was used accelerated the deterioration of the foam compression inserts. The inserts help maintain the packing of the soda lime bed. They act as a cushion to prevent breakage of the soda lime particles and expand to take up space if minor settling does occur. The rapid deterioration of the foam was probably caused by increased exposure to the caustic solution produced by the moist soda lime. The soda lime was moist because of the water carried into the breathing loop by the exhaled gas. The caustic solution is suspected because very little deterioration was observed in the Store/Test condition. That is, when stored with dry, unused soda lime in a dry breathing loop, the foam inserts did not deteriorate noticeably. Exposure times during normal endurance tests are not long enough to cause rapid deterioration, but close contact with moist soda lime for seven days was probably too severe for the foam.

Multiple uses create another potential hazard not necessarily related to storage. The scrubber endurance rating of 180 minutes, assumes an average CO_2 production rate of 1.6 $L \cdot min^{-1}$. This value was based on empirical data found by Knafelc [8]. By applying a respiratory quotient of 0.9 to the oxygen consumption data a mean CO_2 consumption value of 1.37 ± 0.18 $L \cdot min^{-1}$ was found. To increase the safety factor the 99% confidence interval was used. This increases the value to 1.6 $L \cdot min^{-1}$. In the unmanned test, this is considered an attainable average value for a three hour dive. For shorter dives, 10 to 40 minutes for example, higher CO_2 production rates in the range of 2.5 to 4 $L \cdot min^{-1}$ can be sustained [9, 10]. Consider

an example, Table 1, in which 4 dives are done totalling 180 minutes with an average CO_2 production as shown. The total CO_2 produced during the 180 minutes

Table 1: Example of carbon dioxide (CO2) production during four dives.

Dive #	Average CO_2 Production Rate ($L \cdot min^{-1}$)	Dive Time (minutes)	Total CO2 Production (L)
1	1.5	40	60
2	2.25	40	90
3	1.7	60	102
4	2.1	40	84
Totals		180	336

would be 336 L. This is 48 L more than what would be produced by a diver in a single 180-minute dive with an average CO_2 production of 1.6 $L \cdot min^{-1}$, *i.e.*, 288 L of CO_2. The consequence is lower scrubber endurance. Assuming endurance is directly proportional to total CO_2 load, then, in this example, the endurance would be about 160 minutes. Consequently, for multiple dives, whether storage is involved or not, divers must be conscious of the effect on endurance of short-duration, high exertion dives.

CONCLUSIONS

In conclusion, the results of this experiment indicated that storage of soda lime in the CF rebreathers, CCDA, CUMA and S-10, for up to seven days did not reduce endurance but other factors did arise which restrict how the storage period can be used. The results showed that multiple use of the rebreather during the seven day period did not reduce scrubber endurance. On the other hand, an analysis of factors associated with using and storing the rebreathers revealed that multiple use of the rebreather should be done with caution in sub-freezing conditions. While prescribed pre-cautions can prevent ice fouling, they may not eliminate failures after prolonged sub-freezing storage. Multiple use combined with storage could also produce biological hazards and may prematurely degrade the

foam compression inserts in the scrubber. A final factor in all multiple use rebreather diving was the possible increased carbon dioxide load produced by short-duration, high-exertion dives which would reduce scrubber endurance.

RECOMMENDATIONS

The results of this investigation led to the following recommendations:

a. amend Canadian Forces Diving Manual, B-GG-380-000/FP-004, to include the seven day pre-preparation period;

b. performing multiple use dives combined with storage between dives was not recommended (storing wet diving equipment is never recommended); however, if necessary, make all attempts to clean breathing loop daily;

c. take pre-cautions as per Canadian Forces Diving Manual [7] when operating in sub-freezing temperatures;

d. develop an adjustment that can be applied to rated scrubber endurance to account for short-duration, high exertion dives; and

e. attempt to improve the material of scrubber foam compression inserts.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Robert MacLean for his efforts and attention to detail in completing the endurance and activity tests and Leading Seaman J.F. Larcheveque for maintaining all the rebreathers in good working order.

REFERENCES

1. Canadian Forces Diving Manual, Volume 4, Self Contained Mixed-Gas Diving, Book 2 of 2, B-GG-380-000/FP-004, National Defence, Director of Diving Safety, Article 3103, para 3, pp 3-4, 3-5, 1991-08-08, Amendment No. 4.

2. Frew J and Eaton DJ (1995) Optimum combination of carbon dioxide absorbent and scrubber canister for mission and emergency use in Submersible Diver Lockout 1 (SDL-1), DCIEM No. 95-16, Defence and Civil Institute of Environmental Medicine, North York, Ontario.

3. Specification for Soda Lime Used for the Removal of Carbon Dioxide in Underwater Breathing Apparatus, D-87-003-001/SF-000, National Defence, Director of Ships Engineering, 1992-12-01.

4. NATO Underwater Working Party - Ad Hoc Technical Sub Group. (1995) Standard Unmanned Test Procedures for Underwater Breathing Apparatus, NATO Study 1410UD, 4th Preliminary Draft.

5. Canadian Forces Diving Manual, Volume 4, Self Contained Mixed-Gas Diving, Book 1 of 2, B-GG-380-000/FP-004, National Defence, Director of Diving Safety, Article 5103, para 9, 1991-08-08, Amendment No. 4.

6. Presswood CG (1986) Unmanned evaluation of five carbon dioxide absorbents which were frozen prior to use with the Draeger Lar V UBA. NEDU Report 3-86, Navy Experimental Diving Unit, Panama City, Florida.

7. Canadian Forces Diving Manual, Volume 4, Self Contained Mixed-Gas Diving, Book 1 of 2, B-GG-380-000/FP-004, National Defence, Director of Diving Safety, Article 5201, para 9, 1991-08-08, Amendment No. 4.

8. Knafelc ME (1989) Oxygen consumption rate of operational underwater swimmers. NEDU Report 1-89, Navy Experimental Diving Unit, Panama City, Florida.

9. Donald KW and Davidson WM (1954) Oxygen uptake of 'booted' and 'fin swimming' divers. *Journal of Applied Physiology*, 7: 31-37.

10. Morrison JB (1973) Oxygen uptake studies of divers when fin swimming with maximum effort at depths of 6-176 feet. *Aerospace Medicine*, 44: 1120-1129.

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Establishment sponsoring a contractor's report, or tasking agency, are entered in section 12.)	2. DOCUMENT SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)
Defence and Civil Institute of Environmental Medicine P.O. Box 2000, 1133 Sheppard Avenue West North York, Ontario, M3M 3B9	UNCLASSIFIED

3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated be the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

Effects on scrubber endurance of storing soda lime in CF Rebreathers.

4. DESCRIPTIVE NOTES (the category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Final Report

5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Burns, Maj. Frank E.)

Eaton, David J.

6. DOCUMENT DATE (month and year of publication of document)	7.a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)	7.b. NO. OF REFS. (total cited in document)
Nov 95	16	10

8.a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)	8.b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

9.a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	9.b. OTHER DOCUMENT NO.(S) (any other numbers which may be assigned this document either by the originator or by the sponsor.)
DCIEM No. 95-47	

10. DOCUMENT AVAILABILITY (any limitation on further dissemination of the document, other than those imposed by security classification)

X	Unlimited distribution
	Distribution limited to defence departments and defence contractors; further distribution only as approved
	Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
	Distribution limited to government departments and agencies; further distribution only as approved
	Distribution limited to defence departments; further distribution only as approved
	Other

11. ANNOUNCEMENT AVAILABILITY (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (10.) However, where further distribution (beyond the audience specified in 10) is possible, a wider announcement audience may be selected.)

NIL

12. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

Chief of Staff J3

DSIS DCD03
HFD 09/94

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

Canadian Forces divers using rebreather diving apparatus are currently restricted to pre-dive preparation times of only 6 hours. A proposal was made to increase this time to 7 days. Theoretically, this was possible; however, no empirical data were available to indicate that the chemical carbon dioxide absorbent could survive an extended storage period in Canadian Forces rebreathers. Consequently, the Experimental Diving Unit of the Defence and Civil Institute of Environmental Medicine conducted a study to determine if storage of soda lime would reduce the carbon dioxide scrubber endurance. The tests measured scrubber endurance using proposed NATO standard procedures under three conditions: (a) no storage; (b) seven days of storage; and (c) 1 hour under the endurance test conditions, followed by 7 days storage and then completion of the endurance test. The results indicated no difference between the three conditions; thereby, supporting the proposal for up to 7 days of storage. On the other hand, issues related to cold weather operations, biological hazards, heavy exertion and accelerated material wear imposed some restrictions on rebreather storage.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Carbon dioxide scrubber
Underwater Breathing Apparatus
UBA
Rebreather
Closed-circuit Breathing Apparatus
Semi-closed circuit Breathing Apparatus
Soda Lime
Endurance
Shelf Life
CUMA
CCDA
S-10
Siva 55
Siva+
Diving
Mine Countermeasures
Carbon dioxide
Carbon dioxide scrubber
Carbon dioxide absorbent
Break through